MODIS Collection 4 Active Fire Product User's Guide Version 2.2

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1 Introduction

This document contains the most current information about the Terra and Aqua Moderate Resolution Imaging Spectrometer (MODIS) fire products. It is intended to provide the end user with practical information regarding their use and misuse, and to explain some of the more obscure and potentially confusing aspects of the fire products and MODIS products in general.

2 Overview of the MODIS Active Fire Products

Here we provide a general overview of the MODIS active fire products. More detailed descriptions of these products and example ingest code can be found in Section 4.

2.1 Terminology

Before proceeding with a description of the MODIS Fire Products, we must briefly describe some of the terminology that you will encounter when ordering and working with MODIS products. Specifically, we'll define the terms *granule*, *tile*, and *collection*, and the acronym CMG, as each applies to the MODIS products.

2.1.1 Granules

A *granule* is simply an unprojected segment of the MODIS orbital swath containing about 5 minutes of data. MODIS Level 0, Level 1, and Level 2 products are granule-based.

2.1.2 Tiles

MODIS Level 2G, Level 3, and Level 4 products are defined on a global 250 m, 500 m, or 1 km sinusoidal grid (the particular spatial resolution is product-dependent). Because these grids are unmanageably large in their entirety (43200 $\times$ 21600 pixels at 1 km, and 172800 $\times$ 86400 pixels at 250 m), they are divided into fixed tiles approximately $10^\circ \times 10^\circ$ in size. Each tile is assigned a horizontal (H) and vertical (V) coordinate, ranging from 0 to 35 and 0 to 17, respectively (Figure 1). The tile in the upper left (i.e. northernmost and westernmost) corner is numbered (0,0).

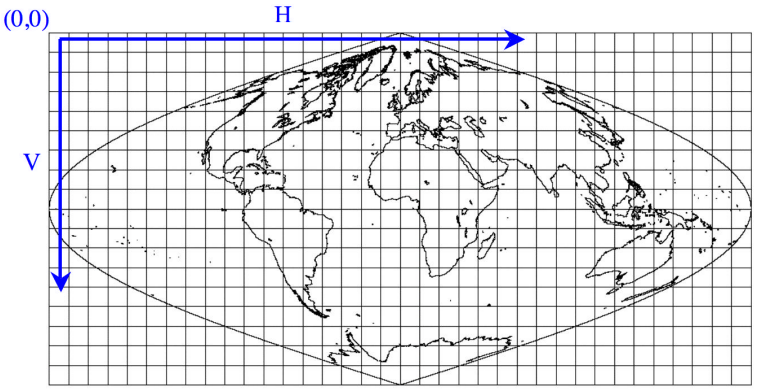


Figure 1: MODIS tiling scheme.

2.1.3 Climate Modeling Grid (CMG)

MODIS Level 3 and Level 4 products can also be defined on a coarser-resolution *Climate Modelling Grid* (CMG). The objective is to provide the MODIS land products at consistent low resolution spatial and temporal scales suitable for global modeling. In practice, there is a fair amount of variation in the spatial and temporal gridding conventions used among the MODIS land CMG products.

2.1.4 Collections

Reprocessing of the entire MODIS data archive is periodically performed so as to incorporate better calibration, algorithm refinements, and improved upstream products into all MODIS products. The updated MODIS data archive resulting from each reprocessing is referred to as a *collection*. Later collections supersede all earlier collections.

For the Terra MODIS, Collection 1 consists of the first products generated following launch. Terra MODIS data were first reprocessed for the first time in June 2001 to produce Collection 3. Note that this first reprocessing was numbered Collection 3, rather than Collection 2, as one would expect. Collection 3 was also the first produced for the Aqua MODIS products. Collection 4 reprocessing was initiated in December 2002 for the Terra MODIS, and somewhat later for the Aqua MODIS, and it forms the current archive of the MODIS products. Currently, Collection 5 reprocessing is scheduled to begin in early 2006.

2.2 Level 2 Fire Products: MOD14 (Terra) and MYD14 (Aqua)

This is the most basic fire product in which active fires and other thermal anomalies, such as volcanoes, are identified. The Level 2 product is defined in the MODIS orbit geometry covering an area of approximately 2340 by 2030 km in the across- and along-track directions, respectively. It is used to generate all of the higher-level fire products, and contains the following components:

- An active fire mask that flags fires and other relevant pixels (e.g. cloud);
- a pixel-level quality assurance (QA) image that includes 19 bits of QA information about each pixel;
- a fire-pixel table which provides 19 separate pieces of radiometric and internal-algorithm information about each fire pixel detected within a granule;
- extensive mandatory and product-specific metadata;
- a grid-related data layer to simplify production of the Climate Modeling Grid (CMG) fire product (Section 2.6).

Product-specific metadata within the Level 2 fire product includes the number of cloud, water, non-fire, fire, unknown, and other pixels occurring within a granule to simplify identification of granules containing fire activity.

Figure 2 shows an example of the active fire mask for the Terra granule acquired on 19 August 2002 at 03:00. In this image, water is shown in blue, clouds in violet, non-fire land pixels in grey, and fire pixels in white. The bottom edge of the image points in the satellite's along-track direction.

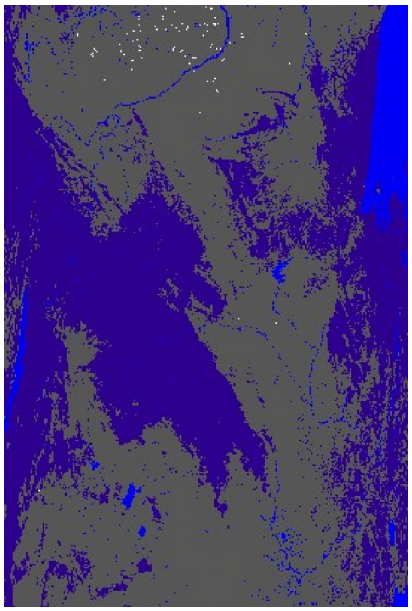


Figure 2: Example MOD14 granule with water shown in blue, clouds in purple, clear land in grey, and active fires in white. The along-track direction points toward the top of the page.

2.3 Level 2G Daytime and Nighttime Fire Products: MOD14GD/MOD14GN (Terra) and MYD14GD/MYD14GN (Aqua)

The Level 2 active fire products sensed over daytime and nighttime periods are binned without resampling into an intermediate data format referred to as Level 2G. The Level 2G format provides a convenient geocoded data structure for storing granules and enables the flexibility for subsequent temporal compositing and reprojection. The Level 2G fire products are a temporary, intermediate data source used solely for producing the Level 3 fire products and are consequently not available from the permanent MODIS data archive.

2.4 Level 3 8-Day Daily Composite Fire Products: MOD14A1 (Terra) and MYD14A1 (Aqua)

The MODIS daily Level 3 fire product is tile based, with each product file spanning one of the 460 MODIS tiles, 326 of which contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each daily (24-hour) compositing period. For convenience, eight days of data are packaged into a single file.

Figure 3 shows the Terra fire mask for 19 September 2001 from the 14-21 September 2001 daily Level 3 fire product (Collection 4). The tile is located in Northern Australia (H31V10). In this image, water is shown in blue, clouds in violet, non-fire land pixels in grey, “unknown” pixels in yellow, and fire pixels in white.

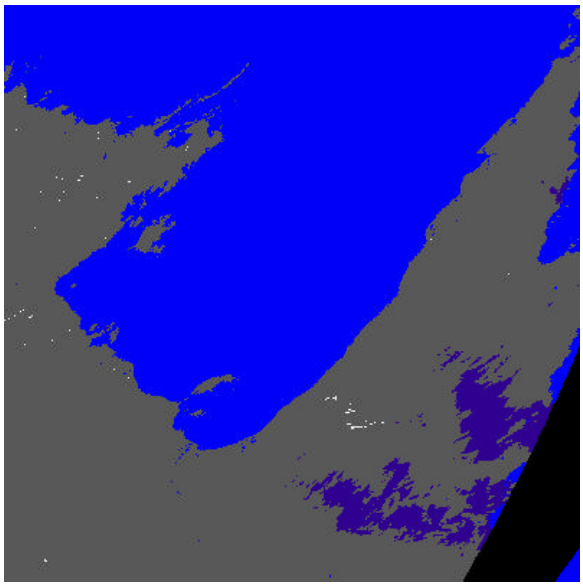


Figure 3: Example of MOD14A1 fire mask for a tile in Northern Australia. Water is shown in blue, clouds in violet, non-fire land pixels in grey, and fire pixels in white.

2.5 Level 3 8-Day Summary Fire Products: MOD14A2 (Terra) and MYD14A2 (Aqua)

The MODIS daily Level 3 8-day summary fire product is tile-based, with each product file spanning one of the 460 MODIS tiles, of which 326 contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each 8-day compositing period.

Figure 4 shows the 8-day summary fire mask from the 26 June - 3 July 2002 8-day Level 3 Terra fire product. The tile is located in the eastern United States (H08V05). The 8-day composite is the maximum value of the individual Level 2 pixel classes that fell into each 1-km grid cell over the entire 8-day compositing period. Due to the way the three different fire-pixel confidence levels are defined (Section 4.1), the Level 3 8-day fire product is sometimes said to contain the "most-confident detected fires". This description can sometimes be misleading in that pixel values are defined even for those grid cells in which no fire pixels were detected.

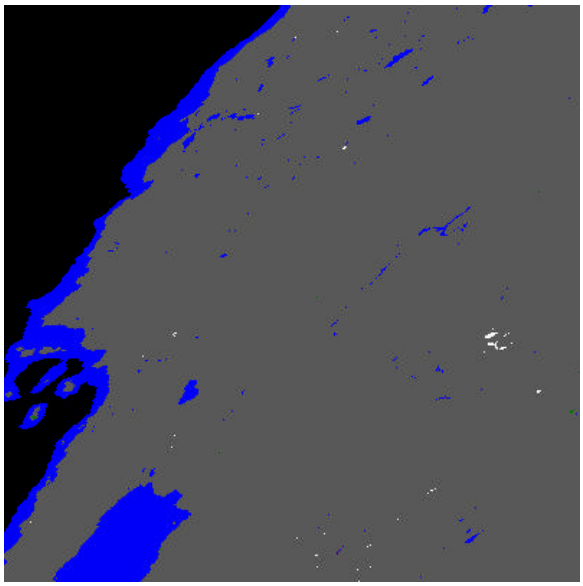
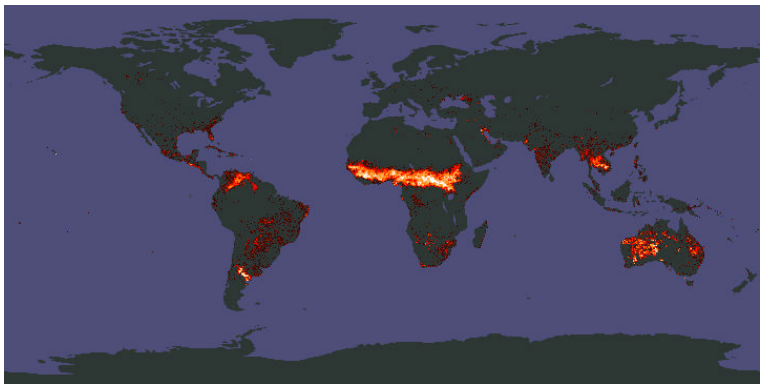


Figure 4: Example of 8-day MOD14A2 fire mask for a tile in eastern United States. Water is shown in blue, clouds in violet, non-fire land pixels in grey, and fire pixels in white.

2.6 Climate Modeling Grid Fire Products (MOD14CMH, MYD4CMH, etc.)

The CMG fire products are gridded statistical summaries of fire pixel information intended for use in regional and global modeling. The products are currently generated at 0.5° spatial resolution for time periods of one calendar month (MOD14CMH/MYD14CMH) and eight days (MOD14C8H/MYD14C8H). Higher resolution 0.25° CMG fire products will eventually be produced as well. An example of the corrected fire pixel count layer of the product is shown in Figure 5.

Figure 5: Example of the corrected fire pixel count data layer from the January 2001 CMG fire product.



2.7 The Rapid Response Fire Products

The MODIS Rapid Response System produces near-real time global imagery including true- and false-color corrected reflectance superimposed with fire locations (Figure X), Normalized Difference Vegetation Index (NDVI), and land surface temperature. Burned area maps will be added in the near future. The locations of Terra and Aqua MODIS fire pixels are also available in ASCII files. For further information see the MODIS Rapid Response web site[1].

[1] `http://rapidfire.sci.gsfc.nasa.gov`

3 Obtaining the MODIS Active Fire Products

All MODIS products are available to users free of charge. There are currently three different ways to obtain the MODIS fire products. Not all products are available through each of these methods. See Table 1.

Table 1: MODIS fire product availability.

Product	Source
Level 2 and most Level 3 fire products:	
MOD14, MYD14	
MOD14A1, MYD14A1	
MOD14A2, MYD14A2	EOS Data Gateway (see Section 3.1).
Level 2G fire products:	
MOD14GD, MOD14GN	
MYD14GD, MYD14GN	Unavailable (not archived).
CMG fire products:	
MOD14CMH, MYD14CMH	
MOD14C8H, MYD14C8H	University of Maryland (see Section 3.2).
Active fire locations in ASCII and ESRI shape file format.	MODIS Web Fire Mapper
Fire and corrected-reflectance JPEG imagery and ASCII fire locations.	MODIS Land Rapid Response System

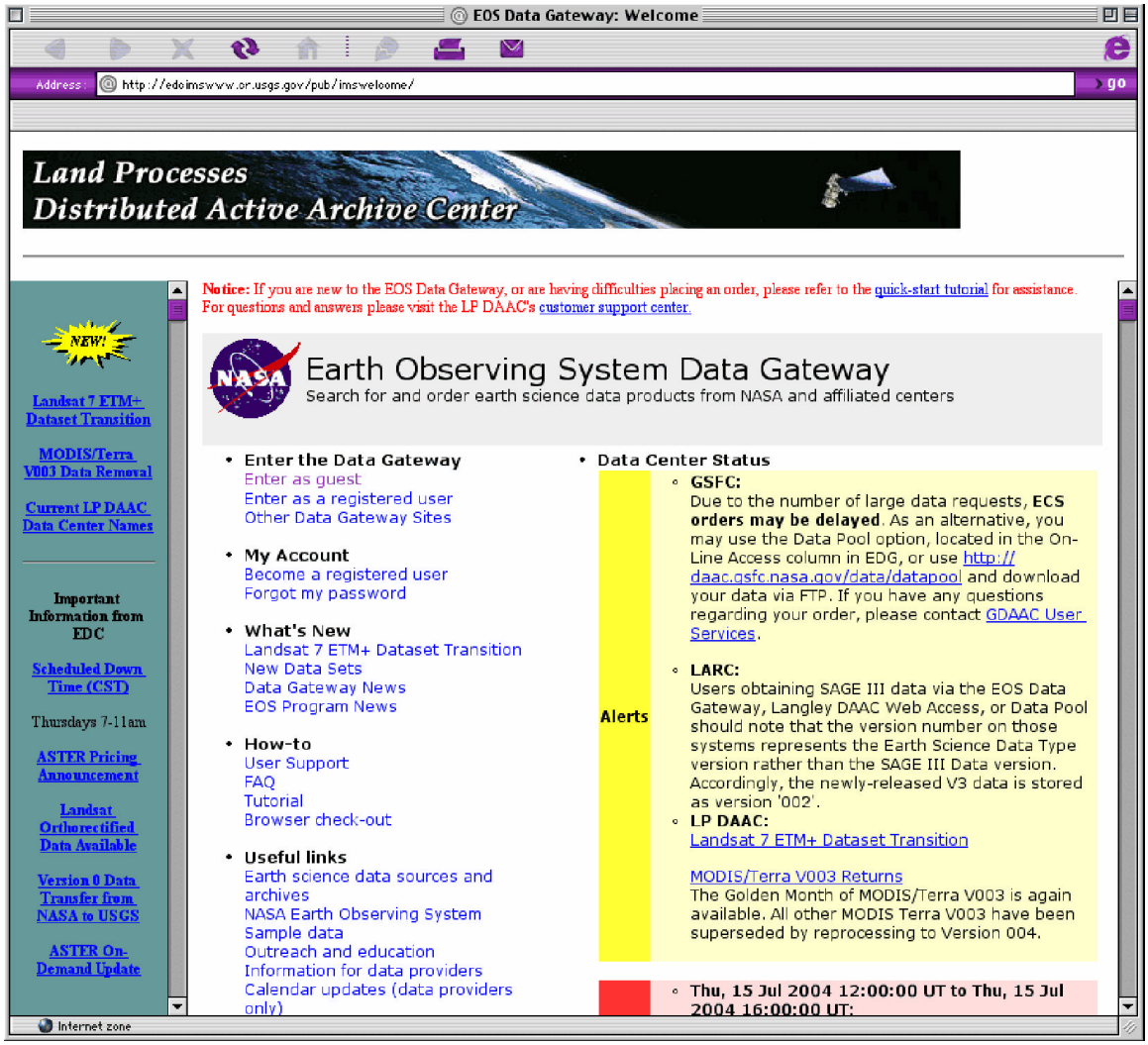
3.1 The EOS Data Gateway (EDG)

Most of the MODIS land products may be obtained from the Land Processes Distributed Active Archive Center (LP-DAAC) using a Web-based interface known as the *EOS Data Gateway* (EDG). Below is a brief tutorial for using the EDG to order the fire products.

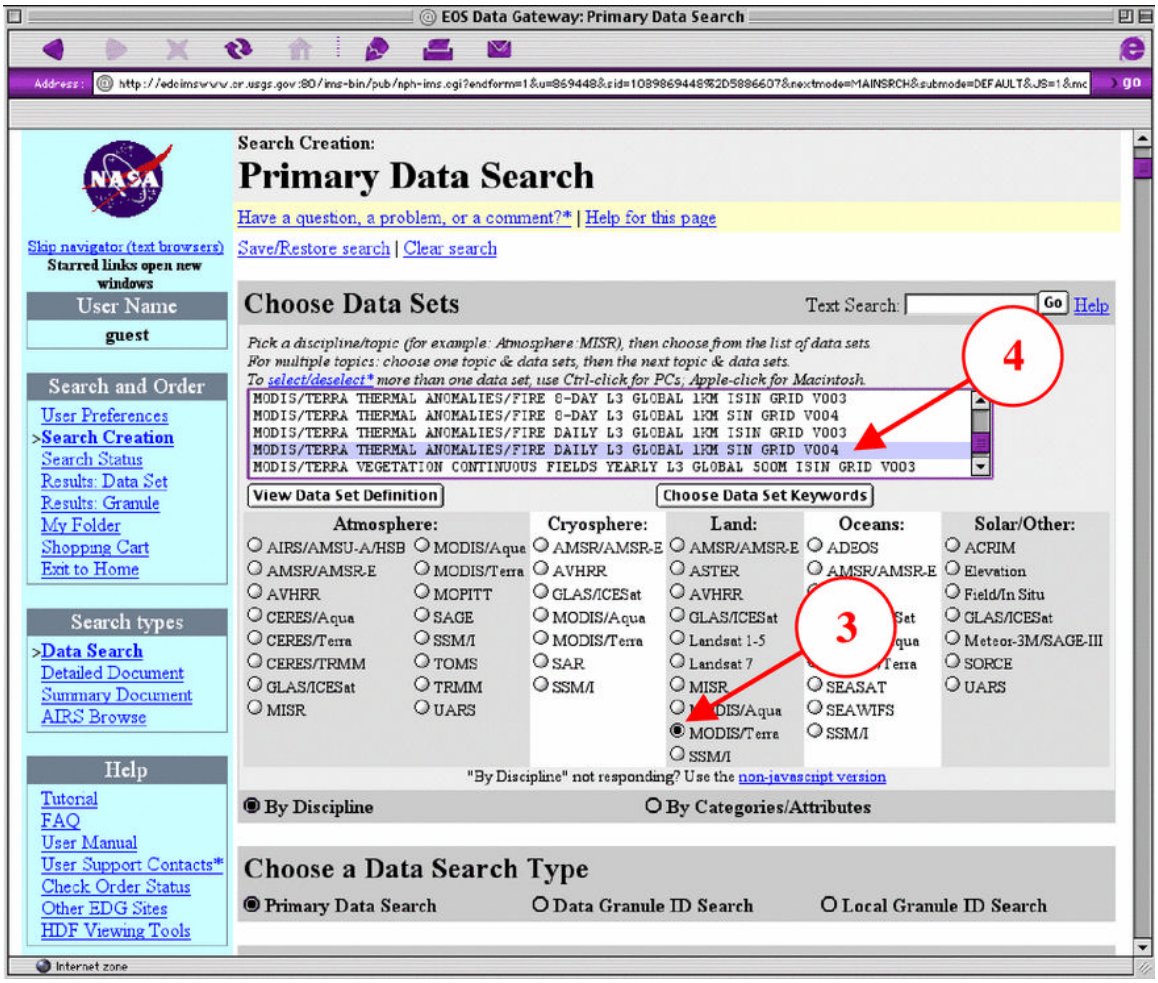
1. Go to the LP-DAAC EOS Data Gateway web site (shown below):

   `http://edcimswww.cr.usgs.gov/pub/imswelcome/`

   The EOS Data Gateway is also available from other DAACs. You may order the MODIS fire products from any of these alternate sites since they "talk" to one another, but the fire products are in fact archived only at the LP-DAAC. Regardless of which particular EDG you use, therefore, the Level 2 and Level 3 fire products will end up coming from the LP-DAAC.


EOS Data Gateway: Welcome
Address: http://edcimswww.cr.usgs.gov/pub/imswelcome/
go
Land Processes
Distributed Active Archive Center
Notice: If you are new to the EOS Data Gateway, or are having difficulties placing an order, please refer to the quick-start tutorial for assistance.
For questions and answers please visit the LP DAAC's customer support center.
NEW!
Landsat 7 ETM+ Dataset Transition
MODIS/Terra V003 Data Removal
Current LP DAAC Data Center Names
Important Information from EDC
Scheduled Down Time (CST)
Thursdays 7-11am
ASTER Pricing Announcement
Landsat Orthorectified Data Available
Version 0 Data Transfer from NASA to USGS
ASTER On-Demand Update
Earth Observing System Data Gateway
Search for and order earth science data products from NASA and affiliated centers
Enter the Data Gateway
Enter as guest
Enter as a registered user
Other Data Gateway Sites
My Account
Become a registered user
Forgot my password
What's New
Landsat 7 ETM+ Dataset Transition
New Data Sets
Data Gateway News
EOS Program News
How-to
User Support
FAQ
Tutorial
Browser check-out
Useful links
Earth science data sources and archives
NASA Earth Observing System
Sample data
Outreach and education
Information for data providers
Calendar updates (data providers only)
Data Center Status
Alerts
GSFC:
Due to the number of large data requests, ECS orders may be delayed. As an alternative, you may use the Data Pool option, located in the On-Line Access column in EDG, or use http://daac.gsfc.nasa.gov/data/datapool and download your data via FTP. If you have any questions regarding your order, please contact GDAAC User Services.
LARC:
Users obtaining SAGE III data via the EOS Data Gateway, Langley DAAC Web Access, or Data Pool should note that the version number on those systems represents the Earth Science Data Type version rather than the SAGE III Data version. Accordingly, the newly-released V3 data is stored as version '002'.
LP DAAC:
Landsat 7 ETM+ Dataset Transition
MODIS/Terra V003 Returns
The Golden Month of MODIS/Terra V003 is again available. All other MODIS Terra V003 have been superseded by reprocessing to Version 004.
Thu, 15 Jul 2004 12:00:00 UT to Thu, 15 Jul 2004 16:00:00 UT:
Internet zone

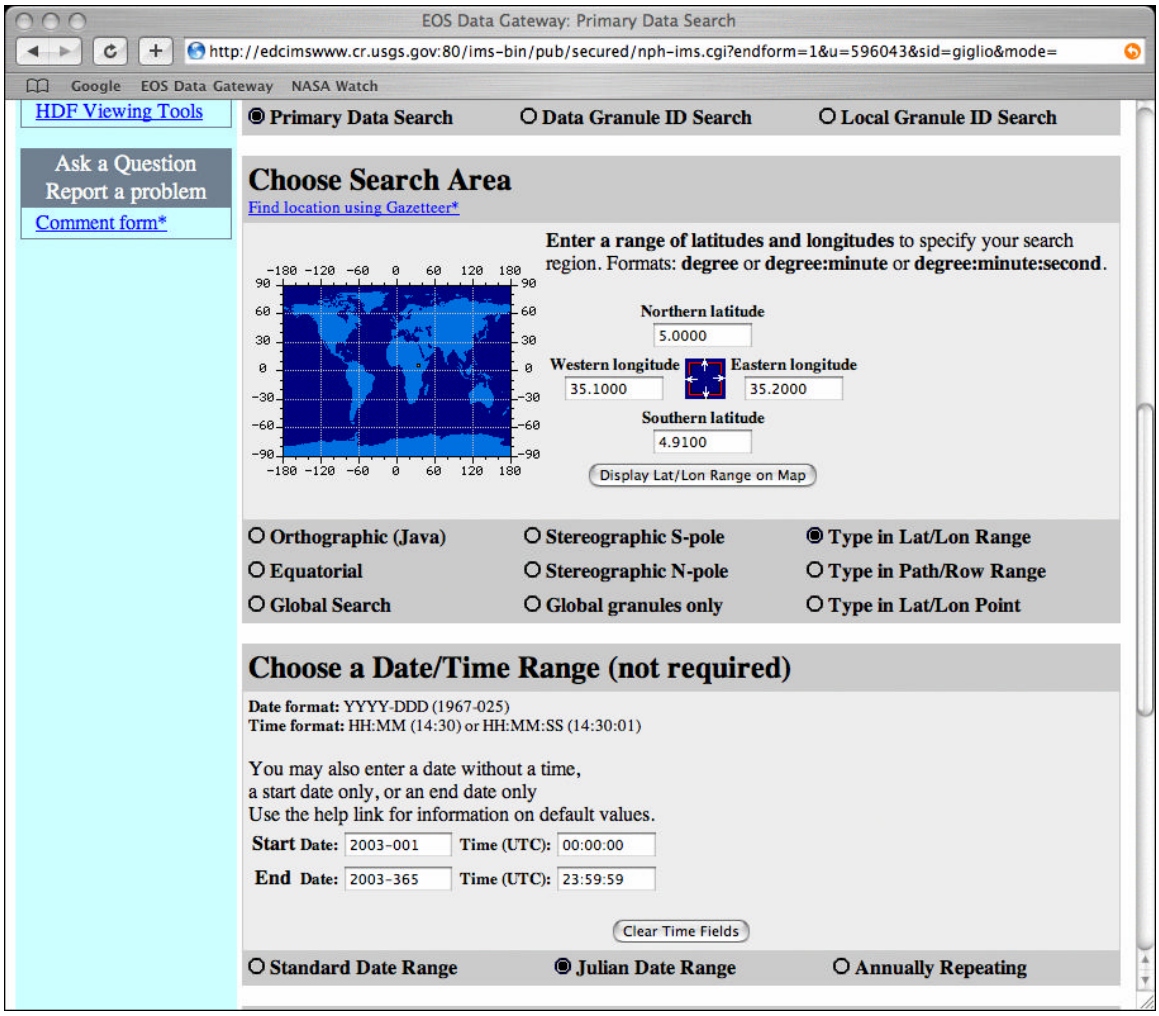
2. Register (select "Become a registered user") or enter as guest. Registering will prevent you from having to reenter contact information each time you place an order. When done registering, enter the Data Gateway ("Enter as registered user").



3. Select either “MODIS/Terra” or “MODIS/Aqua”, depending on the MODIS instrument for which you would like data. If you’d like to order *both* Terra and Aqua MODIS fire data during a single EDG session, choose either button.

4. Scroll through the list box until you find the entry for the particular fire product you’d like to order. Click on it. If you want products from both MODIS instruments go on to Step 5, otherwise skip to Step 6.

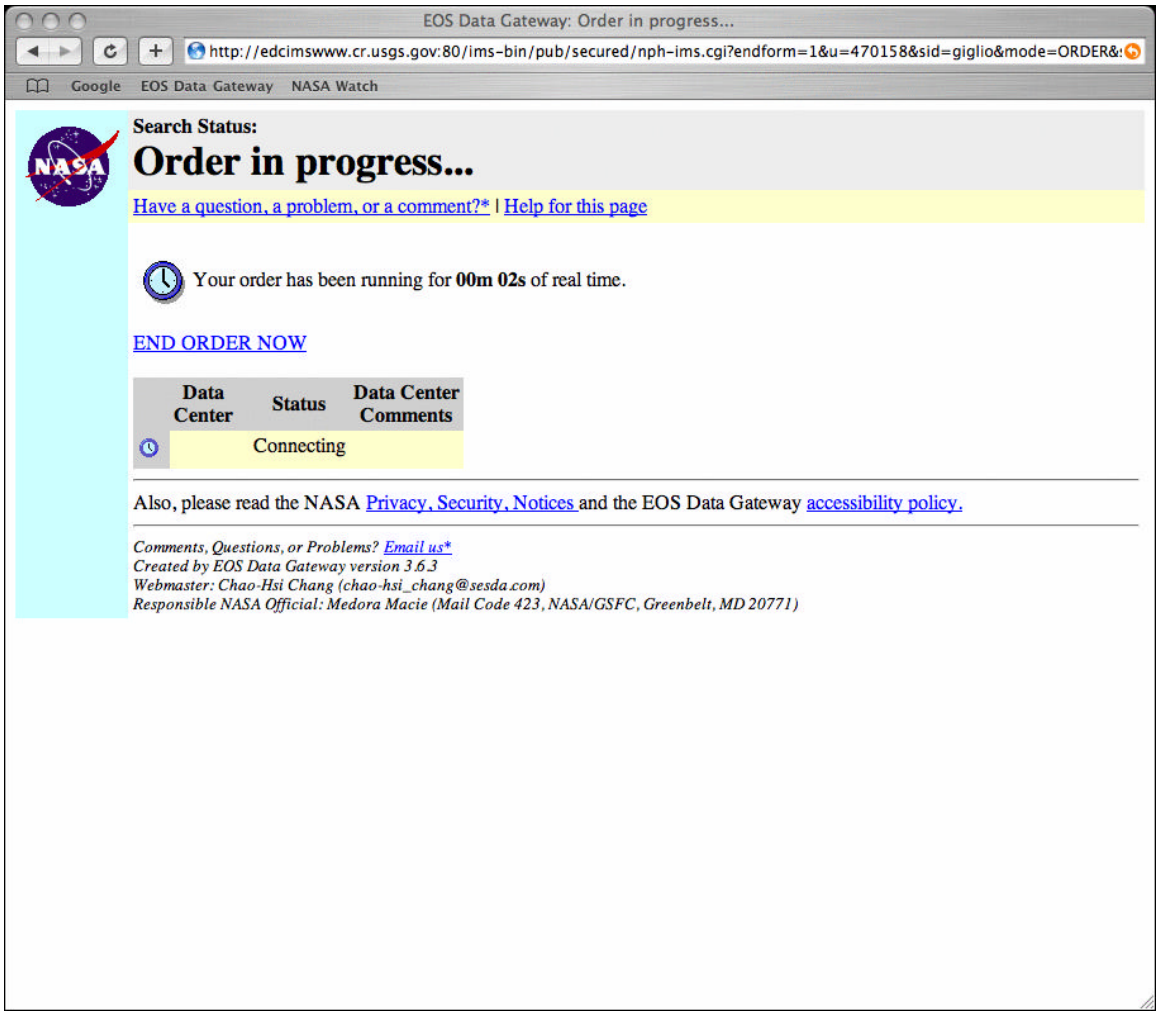
5. (You should only be here if you want to order both Terra and Aqua MODIS fire products. If not, go on to Step 6.) Click on whichever MODIS button you did *not* select in Step 3.



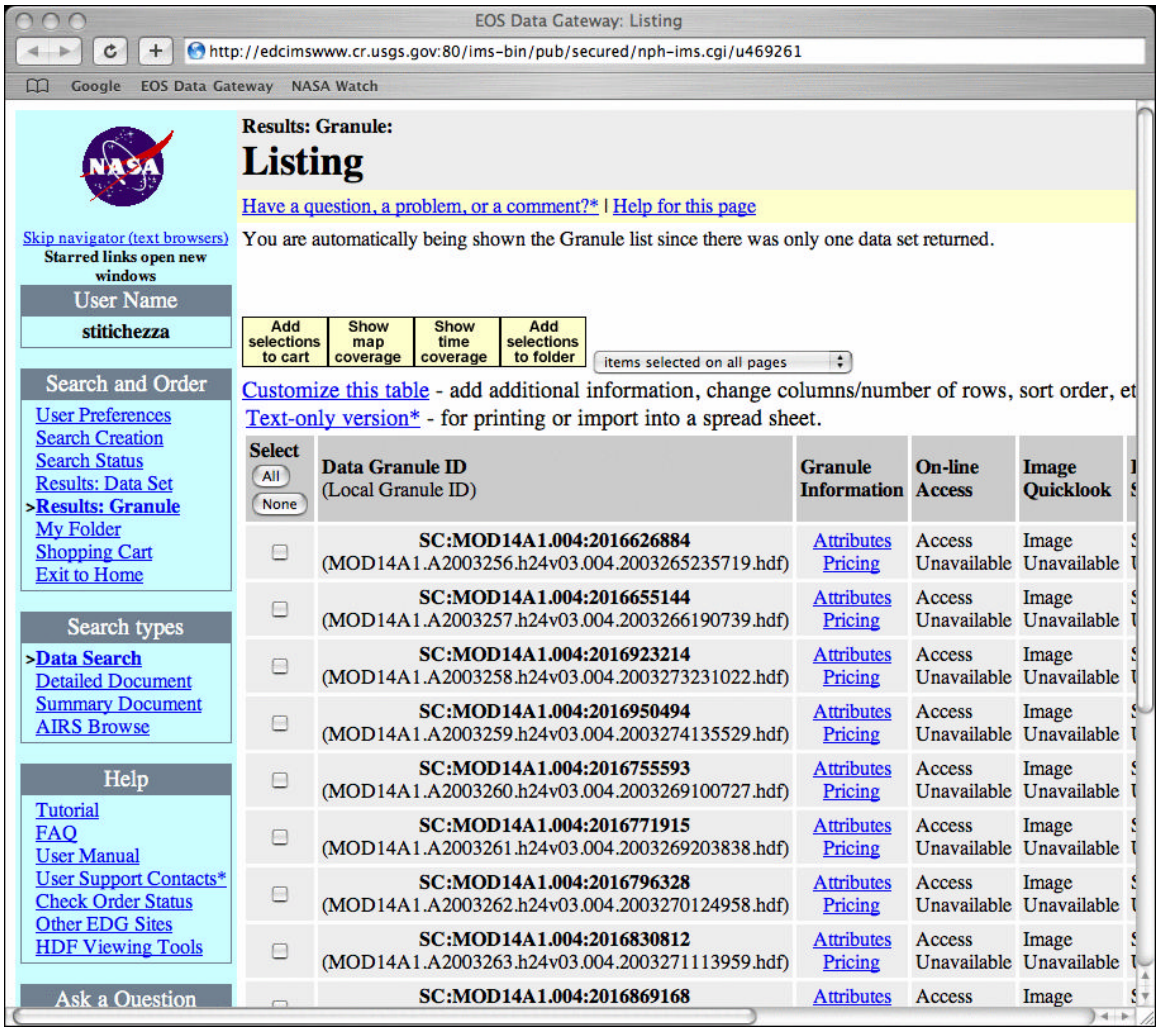
6. In the “Choose Search Area” section of the page, enter latitude and longitude boundaries for the geographic region of interest. To search the entire globe, you can simply select the button “Global Search” (below the map) and save yourself some typing.

7. Choose a time period of interest in the “Choose a Data/Time Range” section of the page.

8. Click on the large pale yellow “Start Search” icon at the bottom of the page.


EOS Data Gateway: Order in progress...
http://edcimswww.cr.usgs.gov:80/ims-bin/pub/secured/nph-ims.cgi?endform=1&u=470158&sid=giglio&mode=ORDER&
Google
EOS Data Gateway
NASA Watch
Search Status:
Order in progress...
Have a question, a problem, or a comment?* | Help for this page
Your order has been running for 00m 02s of real time.
END ORDER NOW
Data Center
Status
Data Center Comments
Connecting
Also, please read the NASA Privacy, Security, Notices and the EOS Data Gateway accessibility policy.
Comments, Questions, or Problems? Email us*
Created by EOS Data Gateway version 3.6.3
Webmaster: Chao-Hsi Chang (chao-hsi_chang@sesda.com)
Responsible NASA Official: Medora Macie (Mail Code 423, NASA/GSFC, Greenbelt, MD 20771)

9. Wait while the system searches for products meeting your search criteria. This usually takes a few minutes.



10. You will presented with a listing of all files matching your search criteria. Select those that you would like to order and click on the yellow “Add selections to cart” button.

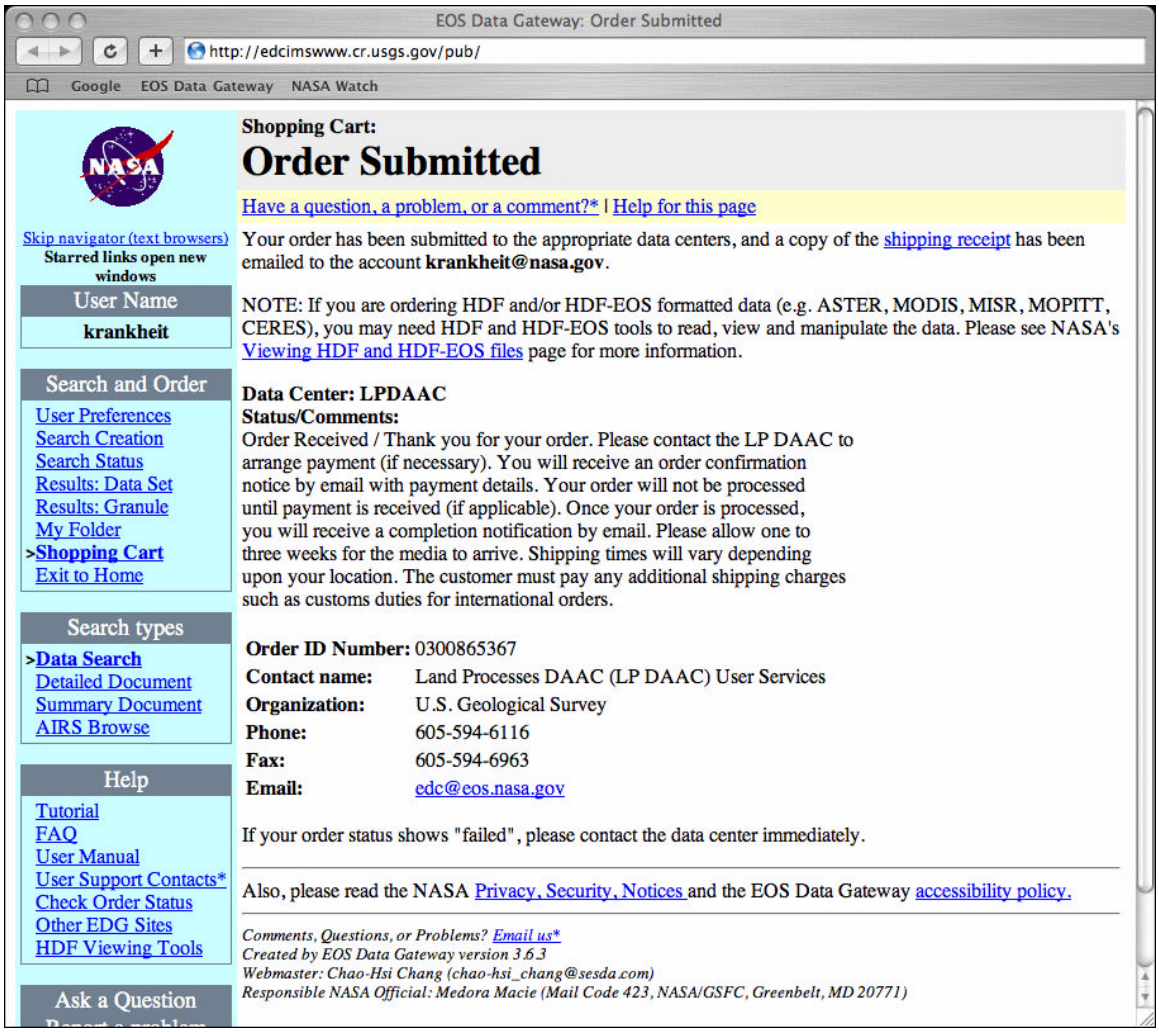
11. The display will change slightly and you may then select a delivery method for the files you have selected. Choose “FtpPull” if you intend to download the data using ftp.

12. Click on the “Go to Step 2: Order Form” button.

13. Update your contact information (or enter it if you are logged in as a guest) and click on the “Submit Order Now!” button.

14. Wait while the system process your request. You will receive updates resembling those in Step 9 while this is happening.

15. When your order has been completed you should see something like this:


EOS Data Gateway: Order Submitted
http://edcimswww.cr.usgs.gov/pub/
Google
EOS Data Gateway
NASA Watch
Skip navigator (text browsers)
Starred links open new windows
User Name
krankheit
Search and Order
User Preferences
Search Creation
Search Status
Results: Data Set
Results: Granule
My Folder
>Shopping Cart
Exit to Home
Search types
>Data Search
Detailed Document
Summary Document
AIRS Browse
Help
Tutorial
FAQ
User Manual
User Support Contacts*
Check Order Status
Other EDG Sites
HDF Viewing Tools
Ask a Question
Shopping Cart:
Order Submitted
Have a question, a problem, or a comment?* | Help for this page
Your order has been submitted to the appropriate data centers, and a copy of the shipping receipt has been emailed to the account krankheit@nasa.gov.
NOTE: If you are ordering HDF and/or HDF-EOS formatted data (e.g. ASTER, MODIS, MISR, MOPITT, CERES), you may need HDF and HDF-EOS tools to read, view and manipulate the data. Please see NASA's Viewing HDF and HDF-EOS files page for more information.
Data Center: LPDAAC
Status/Comments:
Order Received / Thank you for your order. Please contact the LP DAAC to arrange payment (if necessary). You will receive an order confirmation notice by email with payment details. Your order will not be processed until payment is received (if applicable). Once your order is processed, you will receive a completion notification by email. Please allow one to three weeks for the media to arrive. Shipping times will vary depending upon your location. The customer must pay any additional shipping charges such as customs duties for international orders.
Order ID Number: 0300865367
Contact name: Land Processes DAAC (LP DAAC) User Services
Organization: U.S. Geological Survey
Phone: 605-594-6116
Fax: 605-594-6963
Email: edc@eos.nasa.gov
If your order status shows "failed", please contact the data center immediately.
Also, please read the NASA Privacy, Security, Notices and the EOS Data Gateway accessibility policy.
Comments, Questions, or Problems? Email us*
Created by EOS Data Gateway version 3.6.3
Webmaster: Chao-Hsi Chang (chao-hsi_chang@sesda.com)
Responsible NASA Official: Medora Macie (Mail Code 423, NASA/GSFC, Greenbelt, MD 20771)

3.2 MODIS CMG Active-Fire Product Distribution

At present the CMG products are distributed from the University of Maryland via the ftp server `fuoco.geog.umd.edu` (login name is `fire` and password is `burnt`) in the directory `modis/cmg`. For convenience, the products are distributed in multiple, standard data formats. Currently HDF and Flexible Image Transport System (FITS) files are available; additional formats may be produced in the future.

4 Detailed Product Descriptions

4.1 MOD14 and MYD14

MOD14/MYD14 is the most basic fire product in which active fires and other thermal anomalies, such as volcanoes, are identified. The Level 2 product is defined in the MODIS orbit geometry covering an area of approximately 2340 by 2030 km in the across- and along-track directions, respectively. It is used to generate all of the higher-level fire products.

4.1.1 Fire Mask

The fire mask is the principle component of the Level 2 MODIS fire product, and is stored as an 8-bit unsigned integer Scientific Data Set (SDS) named "fire mask". In it, individual 1-km pixels are assigned one of nine classes. The meaning of each class is listed in Table 2.

Table 2: MOD14/MYD14 fire mask pixel classes.

Class	Meaning
0	not processed (missing input data)
2	not processed (other reason)
3	water
4	cloud
5	non-fire clear land
6	unknown
7	low-confidence fire
8	nominal-confidence fire
9	high-confidence fire

A pixel class of 1 was defined for historical reasons but will never actually occur in the fire mask.

4.1.2 Detection Confidence

A detection confidence intended to help users gauge the quality of individual fire pixels is included in the Level 2 fire product. This confidence estimate, which ranges between 0% and 100%, is used to assign one of the three fire classes (low-confidence fire, nominal-confidence fire, or high-confidence fire) to all fire pixels within the fire mask.

In some applications errors of comission (or *false alarms*) are particularly undesirable, and for these applications one might be willing to trade a lower detection rate to gain a lower false alarm rate. Conversely, for other applications missing any fire might be especially undesirable, and one might then be willing to tolerate a higher false alarm rate to ensure that fewer true fires are missed. Users requiring fewer false alarms may wish to retain only nominal- and high-confidence fire pixels, and treat low-confidence fire pixels as clear, non-fire, land pixels. Users requiring maximum fire detectability who are able to tolerate a higher incidence of false alarms should consider all three classes of fire pixels.

4.1.3 Algorithm Quality Assessment Bits

Pixel-level QA is stored in a 32-bit unsigned integer SDS named "algorithm QA", with individual fields stored in specific bits. The exact meaning of these bit fields is defined in the Level 2 Fire

Product file specification.

4.1.4 Fire Pixel Table

The fire pixel table is simply a collection of SDSs containing relevant information about individual fire pixels detected within a granule. Due to HDF file format and library limitations, the Fire Pixel Table is stored as 19 separate SDSs. A brief summary of these SDSs is provided in Table 3.

Table 3: Collection 4 Level 2 fire product SDSs comprising the "fire pixel table".

SDS Name	Data Type	Unit	Description
FP_line	int16	-	Granule line of fire pixel.
FP_sample	int16	-	Granule sample of fire pixel.
FP_latitude	float32	degrees	Latitude of fire pixel.
FP_longitude	float32	degrees	Longitude of fire pixel.
FP_R2	float32	-	Near-IR (band 2) reflectance of fire pixel (daytime only).
FP_T21	float32	K	Channel 21/22 brightness temperature of fire pixel.
FP_T31	float32	K	Channel 31 brightness temperature of fire pixel.
FP_MeanT21	float32	K	Background channel 21/22 brightness temperature.
FP_MeanT31	float32	K	Background channel 31 brightness temperature.
FP_MeanDT	float32	K	
FP_MAD_T21	float32	K	
FP_MAD_T31	float32	K	
FP_MAD_DT	float32	K	
FP_power	float32	W m^{-2}	Fire radiative power per unit area.
FP_AdjCloud	uint8	-	Number of adjacent cloud pixels.
FP_AdjWater	uint8	-	Number of adjacent water pixels.
FP_WinSize	uint8	-	Background window size.
FP_NumValid	int16	-	Number of valid background pixels.
FP_confidence	uint8	%	Detection confidence estimate.

4.1.5 Metadata

Every MODIS product carries with it ECS-mandated metadata stored in the HDF global attributes *CoreMetadata.0* and *ArchiveMetadata.0*. Each attribute is an enormous string of ASCII characters encoding many separate metadata fields in Parameter Value Language (PVL). Among other information, the *ArchiveMetadata.0* attribute usually contains product-specific metadata included at the discretion of the PI. However, since the PVL is awkward to read and tedious to parse, we have stored many of the product-specific metadata fields as standard HDF global attributes. These are summarized in Table 4. Descriptions of the product-specific metadata stored in the ECS *ArchiveMetadata.0* attribute may be found in the MOD14/MYD14 file specification (see Section 7.2).

Table 4: MODIS Level 2 fire product metadata stored as standard gobal HDF attributes.

Attribute Name	Description
FirePix	Number of fire pixels detected in granule.
MissingPix	Number of pixels in granule lacking valid data for processing.
LandPix	Number of land pixels in granule.
WaterPix	Number of water pixels in granule.
WaterAdjacentFirePix	Number of fire pixels that are adjacent to one or more water pixels.
CloudAdjacentFirePix	Number of fire pixels that are adjacent to one or more cloud pixels.
UnknownPix	Number of pixels assigned a class of *unknown* in granule.
LandCloudPix	Number of land pixels obscured by cloud in granule.
WaterCloudPix	Number of water pixels obscured by cloud in granule (always 0 since the internal cloud mask is not applied over water pixels).
GlintPix	Number of pixels in granule contaminated with Sun glint.
GlintRejectedPix	Number of tentative fire pixels that were rejected due to apparent Sun glint contamination.
CoastRejectedPix	Number of tentative fire pixels that were rejected due to apparent water contamination of the contextual neighborhood.
HotSurfRejectedPix	Number of tentative fire pixels that were rejected as apparent hot desert surfaces.
DayPix	Number of daytime pixels in granule.
NightPix	Number of nighttime pixels in granule.
Satellite	Name of satellite (“Terra” or “Aqua”).
ProcessVersionNumber	Program version string (e.g. “4.3.3”).
MOD021KM input file	File name of MOD021KM (Terra) or MYD021KM (Aqua) Level 1B radiance input granule.
MOD03 input file	File name of MOD03 (Terra) or MYD03 (Aqua) geolocation input granule.
SystemID	Operating system identification string.

4.1.6 Example Code

Example 1: IDL code for reading the “fire mask” SDS in the MODIS Level 2 fire product.

```
mod14_file = MOD14.A2002177.1830.004.2002192223417.hdf

; open the HDF file for reading
sd_id = HDF_SD_START(mod14_file, /READ)

; find the SDS index to the MOD14 fire mask
index = HDF_SD_NAMETOINDEX(sd_id, 'fire mask')

; select and read the entire fire mask SDS
sds_id = HDF_SD_SELECT(sd_id, index)
HDF_SD_GETDATA, sds_id, fire_mask

; finished with SDS
HDF_SD_ENDACCESS, sds_id

; finished with HDF file
HDF_SD_END, sd_id
```

4.2 MOD14A1 and MYD14A1

The MOD14A1 and MTD14A1 daily Level 3 fire products are tile-based, with each product file spanning one of the 460 MODIS tiles, of which 326 contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each daily (24-hour) compositing period. For convenience, eight days of data are packaged into a single file.

NOTE: The Collection 5 MOD14A1 and MYD14A1 fire products will differ significantly from the current Collection 4 versions of these products. Improvements are being implemented in preparation for an February 2006 Collection 5 reprocessing, and will require changes to the both the structure and meaning of the product data layers. These changes will most likely break existing code written to ingest the Collection 4 MOD14A1 and MYD14A1 products.

4.2.1 Fire Mask

The fire mask is stored as an 8 (or less) $\times$ 1200 $\times$ 1200, 8-bit unsigned integer SDS awkwardly named "most confident detected fire" for historical reasons. The SDS contains eight successive daily fire masks for a specific MODIS tile. Each of these daily masks is a maximum value composite of the Level 2 fire product pixel classes (Table 2) for those swaths overlapping the MODIS tile during that day. Product files containing less than eight days of data will occasionally be encountered during time periods of missing data and should be handled in ingest software.

4.2.2 QA

Each of the daily fire masks has a corresponding QA layer. This layer is simply a copy of the pixel-level QA from the particular swath pixel of the Level 2 product that populates the Level 3 grid cell.

4.2.3 Example Code

Example 2: MATLAB code to read the Level 3 MODIS daily fire mask, using the MATLAB routine `hdfread`. This is probably the easiest way to read individual HDF SDSs in MATLAB.

```
mod14a1_file = 'MOD14A1.A2001289.h23v02.004.2003164035111.hdf'

% read entire "most confident detected fire" SDS in one shot
fire_mask = hdfread(mod14a1_file, 'most confident detected fire');

% display fire mask for the first day in MOD14A1/MYD14A1
% note how image is transposed so that North appears on top
imagesc(fire_mask(:,:,1)');
```

4.3 MOD14A2 and MYD14A2

The MOD14A2 (Terra) and MYD14A2 (Aqua) daily Level 3 8-day summary fire products are tile-based, with each product file spanning one of the 460 MODIS tiles, 326 of which contain land pixels. The product is a 1-km gridded composite of fire pixels detected in each grid cell over each 8-day compositing period.

NOTE: The Collection 5 MOD14A2 and MYD14A2 fire products will differ significantly from the current Collection 4 versions of these products. Improvements are being implemented in preparation for a February 2006 Collection 5 reprocessing, and will require changes to the both the structure and meaning of the product data layers. These changes will most likely break existing code written to ingest the Collection 4 MOD14A2 and MYD14A2 products.

4.3.1 Fire Mask

The fire mask is stored as a 1200 $\times$ 1200 8-bit unsigned integer SDS awkwardly named "most confident detected fire" for historical reasons.

4.3.2 QA

The QA layer contains pixel-level quality assessment information stored in a 1200 $\times$ 1200 8-bit unsigned integer image. Only the two least significant bits are used, and the values stored in this array correspond to the original Land Data Operational Product Evaluation (LDOPE) QA summary. See *Roy et al.* (2002) for more information about these values.

4.3.3 Example Code

Example 3: MATLAB code to read the Level 3 MODIS 8-day fire mask, using the MATLAB routine `hdfread`. This is probably the easiest way to read individual HDF SDSs in MATLAB.

```
mod14a2_file = 'MYD14A2.A2004193.h08v08.004.2004207151726.hdf'

% read entire "most confident detected fire" SDS in one shot
fire_mask = hdfread(mod14a2_file, 'most confident detected fire');

% display fire mask (transposed so that North appears on top)
imagesc(fire_mask');
```

Example 4: Longer version of MATLAB code to read the Level 3 MODIS 8-day fire mask. This is probably the better approach to use if multiple subsets of an SDS will be read in sequence since the HDF file will be opened and closed only once. (The shorter approach using `hdfread` requires that the file be opened and closed for each read.)

```
mod14a2_file = 'MYD14A2.A2004193.h08v08.004.2004207151726.hdf'

sd_id = hdfsd('start', mod14a2_file, 'DFACC_RDONLY');

sds_index = hdfsd('nametoindex', sd_id, 'most confident detected fire');
sds_id = hdfsd('select', sd_id, sds_index);

% prepare to read entire SDS (always 1200 x 1200 pixels in size)
start = [0,0];
edges = [1200,1200];

[fire_mask, status] = hdfsd('readdata', sds_id, start, [], edges);
status = hdfsd('endaccess', sds_id);

status = hdfsd('end', sd_id);


% display fire mask (transposed so that North appears on top)
imagesc(fire_mask');
```

Example 5: C code for reading Level 3 MODIS 8-day fire mask using HDF library functions.

```
#include <stdio.h>
#include <stdlib.h>
#include "mfhdf.h"

#define ROWS 1200
#define COLS 1200

main(int argc, char **argv)
{
        int32 sd_id, sds_index, sds_id;
        int32 rank, data_type, nattr, dim_sizes[MAX_VAR_DIMS];
        int32 start[2], int32 edges[2];

        char *infile;
        int i, j;
        long nfire;
        uint8 fire_mask[ROWS][COLS];


        infile = "MOD14A2.A2002169.h09v05.004.2003240104900.hdf";

        if ((sd_id = SDstart(infile, DFACC_READ)) == FAIL) exit(1);

        start[0] = start[1] = 0;
        edges[0] = ROWS;
        edges[1] = COLS;

        if ((sds_index = SDnametoindex(sd_id,
                "most confident detected fire")) == FAIL) exit(2);
        if ((sds_id = SDselect(sd_id, sds_index)) == FAIL) exit(3);
        if (SDgetinfo(sds_id, (char *) NULL, &rank, dim_sizes, &data_type,
                &nattr) == FAIL) exit(4);

        /* check rank and data type */
        if (rank != 2) exit(5);
        if (data_type != DFNT_UINT8) exit(6);

        if (SDreaddata(sds_id, start, NULL, edges,
                (void *) fire_mask) == FAIL) exit(7);

        if (SDendaccess(sds_id) == FAIL) exit(8);
        if (SDend(sd_id) == FAIL) exit(9);


        /* simple example: count grid cells containing fires */
        nfire = 0;
        for (i = 0; i < ROWS; i++) {
                for (j = 0; j < COLS; j++)
                        if (fire_mask[i][j] >= 7) nfire++;
                }

        printf("%d grid cells containing fires.\n", nfire);

        exit(0);
}
```

4.4 CMG Fire Products (MOD14CMH, MYD14CMH, etc.)

The CMG fire products are gridded statistical summaries of fire pixel information intended for use in regional and global modeling, and are currently generated at 0.5° spatial resolution for time periods of one calendar month (MOD14CMH/MYD14CMH) and eight days (MOD14C8H/MYD14C8H). Higher resolution 0.25° CMG fire products will eventually be produced as well.

At present the CMG products are distributed from the University of Maryland via anonymous ftp (see Section 3.2). For convenience, the products are distributed in multiple, standard data formats. Currently HDF and Flexible Image Transport System (FITS) files are available; additional formats may be produced in the future.

4.4.1 CMG Naming Convention

Monthly CMG fire products. The file names of the monthly CMG product files have the structure `M?D14CM?.YYYYMM.CCC.VV.XXX`, where `M?D14CM?` is a prefix[2] encoding the satellite and product spatial resolution (see Figure 6), `YYYY` is the four-digit product year, `MM` is the two-digit calendar month, `CCC` denotes the Collection (see Section 2.1.4), `VV` denotes the product version within a Collection, and `XXX` is a suffix indicating the file format.

Eight-day CMG fire products. The file names of the 8-day CMG product files have the structure `M?D14C8?.YYYYDDD.CCC.VV.XXX`, where `M?D14C8?` is a prefix encoding the satellite and product spatial resolution (see Figure 6), `YYYY` is the four-digit product year, `DDD` is the two-digit calendar month, `CCC` denotes the Collection (see Section 2.1.4), `VV` denotes the product version within a Collection, and `XXX` is a suffix indicating the file format.

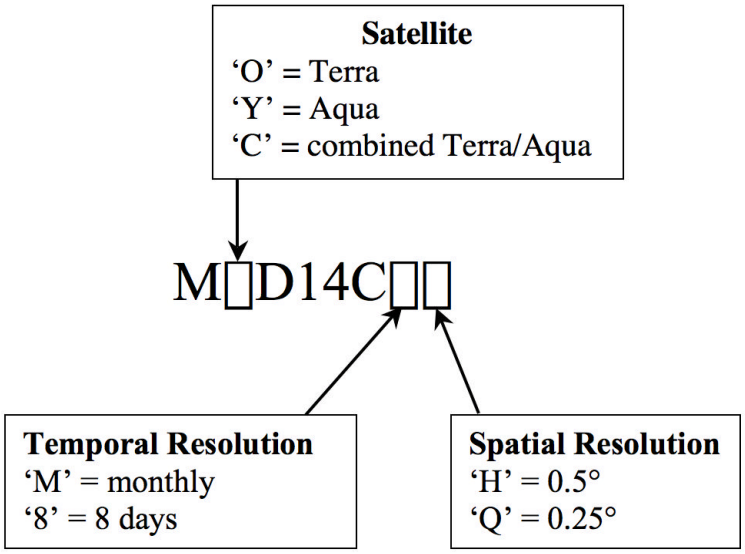


Figure 6: MODIS CMG fire product naming prefix (ESDT) convention.

[2] In MODIS-speak this prefix is usually referred to as an *Earth Science Data Type* (ESDT).

4.4.2 Data Layers

The CMG fire products contain seven separate data layers summarized in Table 5. For the 0.5° products each layer is a 720 × 360 numeric array.

Table 5: Summary of data layers in the CMG fire products.

Layer Name	Data Type	Unit	Description
CorrFirePix	int16	-	Corrected number of fire pixels.
CloudCorrFirePix	int16	-	Corrected number of fire pixels, with an additional correction for cloud cover.
MeanCloudFraction	int8	-	Mean cloud fraction.
RawFirePix	int16	-	Uncorrected count of fire pixels.
CloudPix	int32	-	Number of cloud pixels.
TotalPix	int32	-	Total number of pixels.
MeanPower	float32	MW	Mean fire radiative power.

4.4.3 Global Metadata

Global metadata are stored as global attributes in the HDF product files, and primary-HDU keywords in the FITS product files.

4.4.4 Climate Modeling Grid Navigation

Forward navigation. Given the latitude and longitude (in degrees) of a point on the Earth's surface, the image coordinates (x,y) of the 0.5° CMG grid cell containing this point are computed as follows:

```
y = trunc((90.0 - latitude) / 0.5)

x = trunc((longitude + 180.0) / 0.5)
```

Here trunc denotes truncation of the fractional part of a real number, i.e. trunc(2.2) = 2. These equations yield image coordinates satisfying the inequalities $0 \leq x \leq 719$, $0 \leq y \leq 319$, which are appropriate for programming languages using zero-based array indexing such as C and IDL; for languages using one-based array indexing (e.g. Fortran, MATLAB) add 1.

Inverse navigation. Given coordinates (x,y) of a particular grid cell in the 0.5° CMG fire products, the latitude and longitude (in degrees) of the center of the grid cell may be computed as follows:

```
latitude = 89.75 - 0.5 × y

longitude = -179.75 + 0.5 × x
```

Here, x and y are again zero-based image coordinates; for one-based image coordinates first subtract 1 from both x and y.

4.4.5 Example Code

Example 6: IDL code for reading the cloud-corrected fire pixel layer within the MODIS Collection 4 CMG monthly and 8-day fire products (HDF4 format).

```
; read "CloudCorrFirePix" array in CMG product (HDF4 format)
cmg_file = 'MYD14CMH.200412.004.01.hdf'

sd_id = HDF_SD_START(cmg_file, /READ)
index = HDF_SD_NAMETOINDEX(sd_id, 'CloudCorrFirePix')
sds_id = HDF_SD_SELECT(sd_id, index)
HDF_SD_GETDATA, sds_id, CloudCorrFirePix
HDF_SD_ENDACCESS, sds_id
HDF_SD_END, sd_id
```

Example 7: IDL code for reading the cloud-corrected fire pixel layer within the MODIS Collection 4 CMG monthly and 8-day fire products (FITS format).

```
; read "CloudCorrFirePix" array in CMG product (FITS format)
cmg_file = 'MYD14CMH.200412.004.01.fits'

FITS_OPEN, cmg_file, fcb
ihdu = FIND_HDU(fcb, 'CloudCorrFirePix')
READ_ARRAY, fcb, ihdu, CloudCorrFirePix, ndims, dims
FITS_CLOSE, fcb
```

5 Caveats and known Problems

5.1 Caveats

Some caveats to bear in mind when using the MODIS fire products:

5.1.1 Fire Pixel Locations vs. Gridded Fire Products

We urge caution in using fire pixel locations in lieu of the 1-km gridded MODIS fire products. The former includes no information about cloud cover or missing data and, depending on the sort of analysis that is being performed, it is sometimes possible to derive misleading (or even incorrect) results by not accounting for these other types of pixels. It is also possible to grossly misuse fire pixel locations, even for regions and time periods in which cloud cover and missing observations are negligible. Some caveats to keep in mind when using MODIS fire pixel locations:

- The fire pixel location files allow users to temporally and spatially bin fire counts arbitrarily. However, severe temporal and spatial biases may arise in any MODIS fire time series analysis employing time intervals shorter than about eight days.
- Known fires for which no entries occur in the fire-pixel location files are not necessarily missed by the detection algorithm. Cloud obscuration, a lack of coverage, or a misclassification in the land/sea mask may instead be responsible, but with only the information provided in the fire location files this will be impossible to determine.

5.2 Collection 4 Known Problems

5.2.1 Pre November 2000 Data Quality

Prior to November 2000, the Terra MODIS instrument suffered from several hardware problems that adversely affected all of the MODIS fire products. In particular, some detectors were rendered dead or otherwise unusable in an effort to reduce unexpected crosstalk between many of the 500 m and 1 km bands. The dead detectors are known to introduce at least three specific artifacts in the pre-November 2000 fire products: striping, undetected small fires, and undetected large fires. In some very rare instances severe miscalibration of band-21 in the first weeks of the MODIS data archive (February and March 2000) will cause entire scan lines to be identified as fire.

5.2.2 Regional False Alarms

Recurring false alarms attributed to industrial sources and urban land-cover boundaries have have been observed in eastern China near Shanghai and Shaoxing. A particularly bad example is shown in Figure 7.

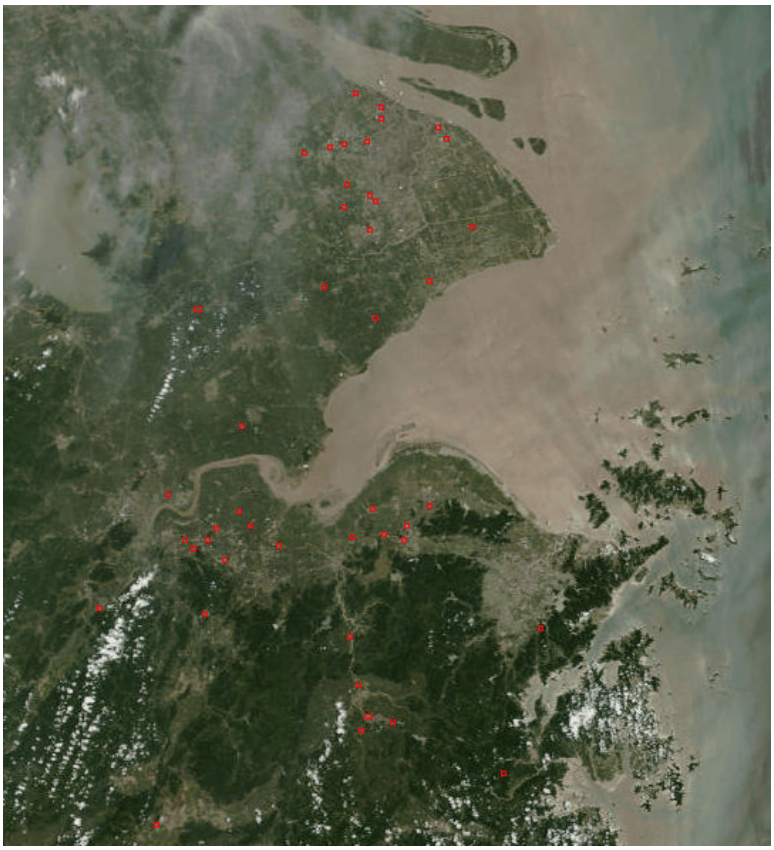


Figure 7: Example of false alarms near Shanghai from the Terra MODIS, 18 July 2004 02:45 UTC. Pixels identified as containing fires are outlined in red, superimposed on a true color corrected reflectance image (courtesy of Jacques Descloitres).

5.2.3 Detection Confidence

A detection confidence intended to help users gauge the quality of individual fire pixels is included in the Level 2 fire product. This confidence estimate, which ranges between 0% and 100%, is used to assign one of the three fire classes (low-confidence fire, nominal-confidence fire, or high-confidence fire) to all fire pixels within the fire mask. In the Collection 4 fire product this confidence estimate does not adequately identify highly questionable, low confidence fire pixels. Such pixels, which by design should have a confidence close to 0%, are too often assigned much higher confidence estimates of 50% or higher. This will be corrected for Collection 5.

6 Frequently Asked Questions

6.1 Terra and Aqua Satellites

6.1.1 Where can I find general information about the Terra and Aqua satellites?

See NASA's Terra and Aqua web sites for a start:

`http://terra.nasa.gov/` `http://aqua.nasa.gov/`

6.1.2 When were the Terra and Aqua satellites launched?

18 December 1999 and 4 May 2002, respectively.

6.2 General MODIS Questions

6.2.1 Where can I find Algorithm Technical Basis Documents (ATBDs) for the MODIS land products?

ATBDs for all of the MODIS land products are available from MODARCH[3]. Note that many are not up to date. In particular, the fire product ATBD pre-dates the launch of both the Terra and Aqua satellites, and describes the very obsolete pre-launch detection algorithm.

6.3 General Fire Product Questions

6.3.1 How are the fires and other thermal anomalies identified in the MODIS fire products detected?

Fire detection is performed using a contextual algorithm (*Giglio et al.*, 2003) that exploits the strong emission of mid-infrared radiation from fires (*Dozier*, 1981; *Matson and Dozier*, 1981). The algorithm examines each pixel of the MODIS swath, and ultimately assigns to each one of the following classes: *missing data*, *cloud*, *water*, *non-fire*, *fire*, or *unknown*.

Pixels lacking valid data are immediately classified as *missing data* and excluded from further consideration. Cloud and water pixels are identified using cloud and water masks, and are assigned the classes *cloud* and *water*, respectively. Processing continues on the remaining clear land pixels. A preliminary classification is used to eliminate obvious non-fire pixels. For those potential fire pixels that remain, an attempt is made to use the neighboring pixels to estimate the radiometric signal of the potential fire pixel in the absence of fire. Valid neighboring pixels in a window centered on the potential fire pixel are identified and are used to estimate a background value. If the background characterization was successful, a series of contextual threshold tests are used to perform a relative fire detection. These look for the characteristic signature of an active fire in which both 4 μm brightness temperature and the 4 and 11 μm brightness temperature difference depart substantially from that of the non-fire background. Relative thresholds are adjusted based on the natural variability of the background. Additional specialized tests are used to eliminate false detections caused by sun glint, desert boundaries, and errors in the water mask. Candidate fire pixels that are not rejected in the course of applying these tests are assigned a class of *fire*. Pixels for which the background characterization could not be performed, i.e. those having an insufficient number of valid pixels, are assigned a class of *unknown*.

[3] `http://modarch.gsfc.nasa.gov/data/atbd/land_atbd.html`

See *Giglio et al.* (2003) for a detailed description of the version 4 detection algorithm.

6.3.2 What is the smallest fire size that can be detected with MODIS? What about the largest?

MODIS can routinely detect both flaming and smoldering fires $\sim$1000 m^2 in size. Under very good observing conditions (e.g. near nadir, little or no smoke, relatively homogeneous land surface, etc.) flaming fires one tenth this size can be detected. Under pristine (and extremely rare) observing conditions even smaller flaming fires $\sim$50 m^2 can be detected.

Unlike most contextual fire detection algorithms designed for satellite sensors that were never intended for fire monitoring (e.g. AVHRR, VIRS, ATSR), there is no upper limit to the largest and/or hottest fire that can be detected with MODIS.

6.3.3 Why didn't MODIS detect a particular fire?

This can happen for any number of reasons. The fire may have started and ended in between satellite overpasses. The fire may be too small or too cool to be detected in the 1 km^2 MODIS footprint. Cloud cover, heavy smoke, or tree canopy may completely obscure a fire. Occasionally the MODIS instruments are inoperable for extended periods of time (e.g. the Terra MODIS in September 2000) and can of course observe nothing during these times.

6.3.4 How do I obtain the MODIS fire products?

See Section 3.

6.3.5 What validation of the MODIS active fire products has been performed?

Validation of the Terra MODIS fire product has primarily been performed using coincident observations from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER); see Morisette et al. (2005) and Morisette et al. (in press) for details. A very brief discussion of the general validation procedure, with some preliminary results, can be found in Justice et al. (2002).

6.3.6 I don't want to bother with strange file formats and/or an unfamiliar ordering interface and/or very large data files. Can't you just give me the locations of fire pixels in plain ASCII files and I'll bin them myself?

You can obtain MODIS fire pixel locations via the Web Fire Mapper, but this doesn't necessarily mean that fire pixel locations are the most appropriate source of fire-related information. The fire pixel location files include no information about cloud cover or missing data, and depending on the sort of analysis you are performing, it is sometimes possible to derive misleading (or even incorrect) results by effectively ignoring these other types of pixels. In many cases it is more appropriate to use one of the 1-km Level 3 or CMG fire products. See Section 5.1.1 for more information about this issue.

6.3.7 How well can MODIS detect understory burns?

The likelihood of detection beneath a tree canopy is unknown but probably very low. Understory fires are usually small, which already makes MODIS less likely to detect them, but with the addition

of a tree canopy to obstruct the view of a fire, detection becomes very unlikely.

6.4 Level 2 Fire Products

6.4.1 Why do the Level 2 product files vary in size?

Level 2 granules can contain slightly different numbers of scans. More importantly, internal HDF compression is used to reduce the size of the files.

6.4.2 How should the different fire detection confidence classes be used?

Three classes of fire pixels (low confidence, nominal confidence, high confidence) are provided in the fire masks of the MODIS Level 2 and Level 3 fire products. Users requiring fewer false alarms may wish to consider only nominal- and high-confidence fire pixels, and treat low-confidence fire pixels as clear, non-fire, land pixels. Users requiring maximum fire detectability, who are able to tolerate a higher incidence of false alarms, should consider all three classes of fire pixels.

6.4.3 How can I take data from the fire-pixel-table SDSs (i.e., the one-dimensional SDSs with the prefix "FP_") and place the values in the proper locations of a two-dimensional array that matches the swath-based "fire mask" and "algorithm QA" SDSs?

1. Open a MOD14/MYD14 Level 2 granule for reading using your favorite programming language.

2. Determine the number of fire pixels in the granule. The easiest way to do this is to read the global HDF attribute "FirePix". (If you are a masochist you can read and parse the ECS *CoreMetadata.0* string for the product specific attribute `FIREPIXELS` instead.) If the number of fire pixels is zero, all of the "FP_" SDSs will have length zero, and there's nothing left to process, so close the file and go on to whatever else you'd like to do.

3. Find the number of lines in the granule. Call this number `nlines`. In the product this quantity corresponds to the dimension `number_of_scan_lines`. Since it is difficult or impossible to determine the value of a named dimension directly with the HDF library, you must instead determine the dimensions of an SDS for which the named dimension applies. You can use either the "fire mask" or "algorithm QA" SDSs for this as they both have dimensions `number_of_scan_lines` by `pixels_per_scan_line`. The HDF library function SDgetinfo returns this information (in IDL use `HDF_SD_GETINFO`).
   You can determine the number of samples too (`pixels_per_scan_line`) if you like, but it will always be 1354.

4. Read the the "FP_line" and "FP_sample" SDSs in their entirety. These arrays contain pixel coordinates within the granule for all of the quantities in the other "FP_" SDSs. Hereafter we'll assume these have been read and stored in internal arrays named `FP_line` and `FP_sample`, respectively.

5. Create a 2-D array to hold whatever "FP_" quantity it is that you'd like to use. Assuming you want the band 21/22 brightness temperature ("FP_T21"), then in IDL you could do this:

   ```
   T21 = fltarr(nlines, 1354)
   ```

6. Read the entire "FP_" SDS that you'd like to use. In the above example this is "FP_T21". Following our earlier convention, we'll assume this SDS is read into an internal array named `FP_T21`.

7. Populate pixels in the T21 array by indexing it with `FP_line` and `FP_sample`. In IDL you would do this in one shot:

   ```
   T21 = FP_T21[FP_line, FP_sample]
   ```

   In non-vector-based languages you'd have to write an explicit loop. In C, for example, do this:

   ```
   for (i = 0; i < num_fire_pixels; i++)
        T21[FP_line[i]][FP_sample[i]] = FP_T21[i];
   ```

   Note that the coordinates in "FP_line" and "FP_sample" are zero-based. In a language like Fortran (with the first array element numbered 1) you'd have to add 1 to all values in `FP_line` and FP_sample.

8. Do whatever you want with the 2-D `T21` array – it can now be indexed just like the fire mask and QA SDSs would be if you had read them from the file. Note, though, that the newly created `T21` array will only contain data in those pixels where fires were detected. This is true for 2-D arrays created from any of the other "FP_" SDSs as well.

9. Go back to step 4 for the remaining "FP_" quantities you want to use.

10. Close the HDF file.

6.4.4 Why are the values of the fire radiative power (FRP) I see in the Level 2 product inconsistent with those I find in the CMG products and published in various journal papers?

The "FP_power" SDS in the Collection 4 Level 2 product actually contains radiative power per unit area, despite the fact that the `units` attribute of this SDS is assigned a value of "megawatts" (this is an error). These values must be multiplied by the appropriate pixel area (at the surface of the Earth) to obtain the FRP. To obtain the FRP in megawatts (MW), use the following formula:

FRP (MW) = power values stored in the Level 2 product $\times$ pixel area (km^2)

Note that the area of a MODIS pixel varies with its position in the MODIS scan; see the next question for details. Note also that starting with Collection 5 the Level 2 products will have this multiplication performed during processing and will therefore contain the correct FRP.

6.4.5 What is the area of a MODIS pixel at the Earth's surface?

The area of a MODIS pixel is nominally 1 km^2 but grows away from nadir. A handy polynomial approximation for the area of a 1-km MODIS pixel (in km^2) as a function of sample number is

$$A_{\text{pixel}}(x) = \sum_{k=0}^{8} c_k x^k \tag{1}$$

where the sample number x = 0, 1, 2, ..., 1353. The coefficients c_k are given in Table 6. This approximation is accurate to within ≈1%, which is less than the error entailed by treating the pixel as having sharp edges. Use double-precision floating point arithmetic when evaluating this polynomial.

Table 6: Polynomial coefficients.

k	c_k (km^2)
0	9.7421684
1	-0.091159223
2	0.00051138175
3	-1.7683231 $\times$ 10^{-6}
4	3.8048273 $\times$ 10^{-9}
5	-5.0660609 $\times$ 10^{-12}
6	4.0471196 $\times$ 10^{-15}
7	-1.7739490 $\times$ 10^{-18}
8	3.2795410 $\times$ 10^{-22}

6.5 Level 3 Tiled Fire Products

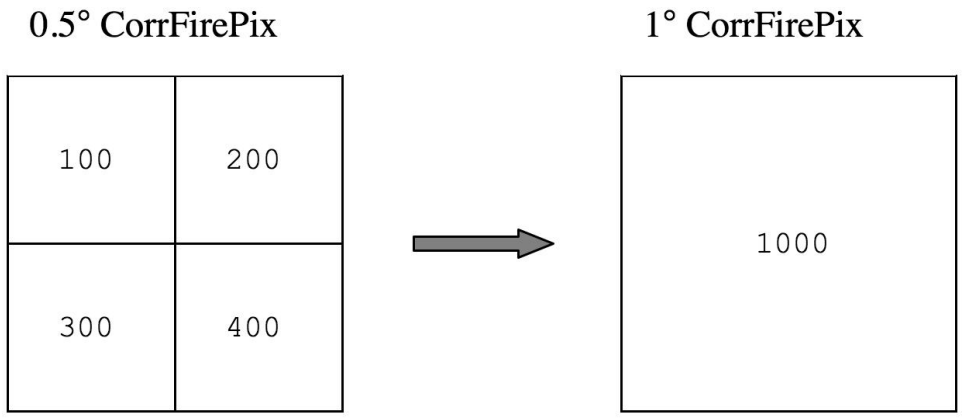
6.5.1 Why do coastlines in the tile-based Level 3 products looked so warped?

The tile-based Level 3 products are defined on a global sinusoidal grid which preserves areas but greatly distorts the shape of land masses at longitudes far from the prime meridian.

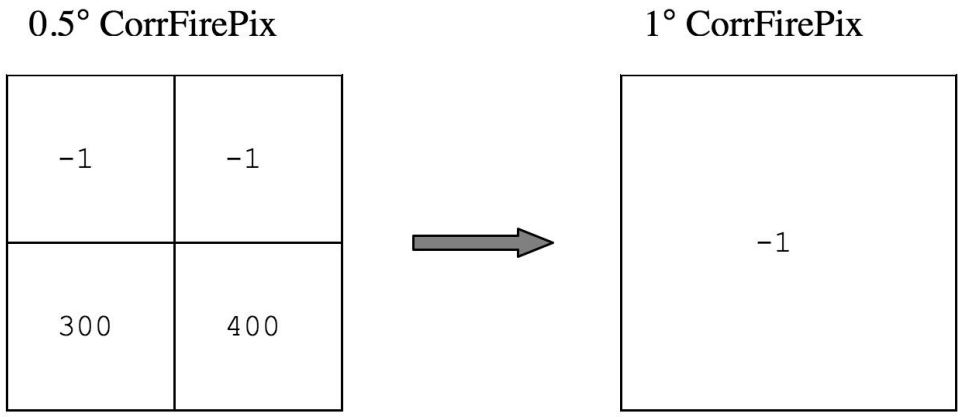
6.6 Level 3 CMG Fire Products

6.6.1 I need to reduce the resolution of the 0.5° CMG fire product to grid cells that are a multiple of 0.5° in size How do I go about doing this?

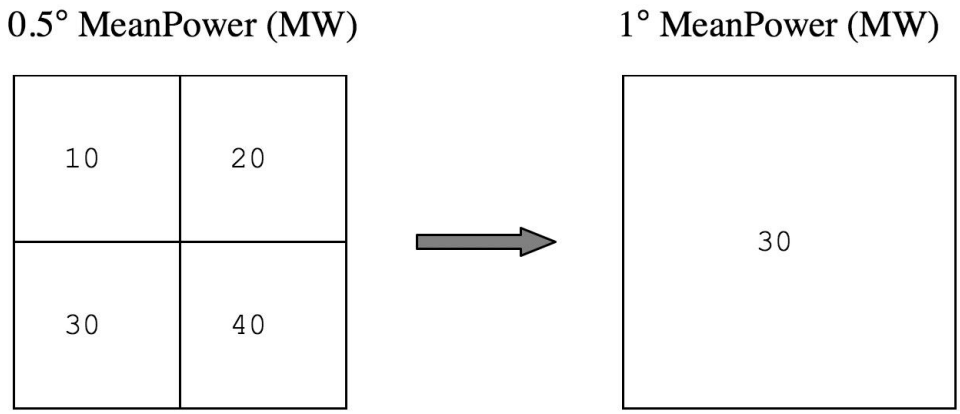
For all pixel-count data layers simply sum the values of the 0.5° grid cells that lie within the larger grid cells. Be sure to handle grid cells flagged with the missing data value of -1. At the very least this entails excluding the negative missing-data values from the resulting sum, but, depending upon the application, it may be more appropriate to flag the coarser grid cell as lacking valid data entirely. When coarsening the mean fire radiative power layer (`MeanPower`) you should weight the individual 0.5° mean FRP values by the corrected fire pixel counts (`CorrFirePix`), handling (by at least excluding) missing FRP values of 0 in the process. A few examples are shown in the following figures:



Rebinning corrected fire pixel counts from 0.5° grid cells (left) to a 1° grid cell (right). The result is simply the sum of the pixel counts of the four 0.5° grid cells (100 + 200 + 300 + 400 = 1000 fire pixels) nested within the 1° grid cell.



Rebinning corrected fire pixel counts from 0.5° grid cells (left) to a 1° grid cell (right) when missing data values of -1 are present. In this case we flag the entire 1° grid cell as lacking valid data which is appropriate when, for example, we are going to compare independent gridded fire products that won't generally have missing data values in exactly the same grid cells. For other applications it would be sufficient to simply exclude the missing values from the sum, yielding a result of 300 + 400 = 700 fire pixels in the 1° grid cell.



Rebinning the mean FRP from 0.5° grid cells (left) to a 1° grid cell (right). The result is the average of the FRP in the four 0.5° grid cells nested within the 1° grid cell, weighted by their individual corrected fire pixel counts. Using the corrected fire pixel counts from the first example (above) this yields:

$$\frac{10\ \mathrm{MW}\times 100+20\ \mathrm{MW}\times 200+30\ \mathrm{MW}\times 300+40\ \mathrm{MW}\times 400}{100+200+300+400} = 30\ \mathrm{MW}$$

6.6.2 Why don't you distribute a daily CMG fire product?

Because a MODIS product at daily temporal resolution will be plagued by extremely large sampling bias errors. At most latitudes a single MODIS instrument simply does not sample the Earth's surface adequately in time periods shorter than about 8 days to "average out" most of the sampling bias.

6.6.3 Why don't you distribute the CMG fire products as plain binary (or ASCII) files?

1) The number of files one must deal with balloons since most users request that individual data layers be written to separate files; 2) it is difficult to include useful metadata without writing separate header files, increasing the total number of files to handle even further; 3) it is possible for data and its accompanying metadata to become separated; and 4) production, ingest, and analysis software is much more likely to break when changes are made to the product.

6.6.4 Where can I find information about the FITS file format?

Information about FITS is available from NASA's FITS Support Office . You may also find the *TRMM VIRS Monthly Fire Product User's Guide* (*Giglio and Kendall*, 2003) helpful, particularly Appendix 2.

6.6.5 How can I display images in FITS files?

Two good choices are *SAOimage*[4] (Figure 8) and *DS9*[5] (Figure 9). Use the "`-ul`" switch with SAOimage and the "`-orient y`" switch with DS9 to orient North upwards, otherwise the grid will appear upside down.

[4] `http://tdc-www.harvard.edu/software/saoimage.html`
[5] `http://hea-www.harvard.edu/RD/ds9/`

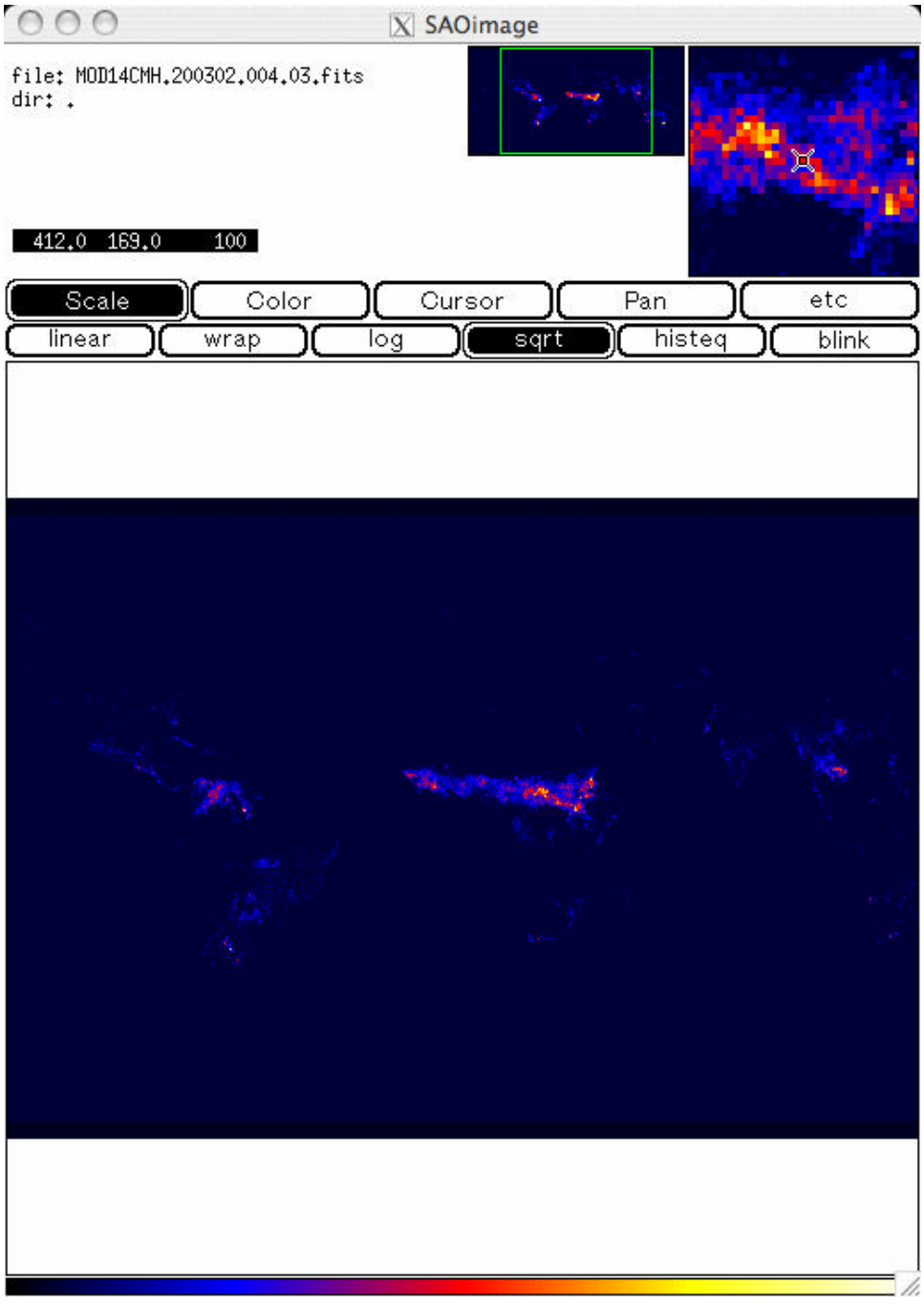


Figure 8: SAOimage displaying the `CorrFirePix` data layer in the February 2003 MOD14CMH product.

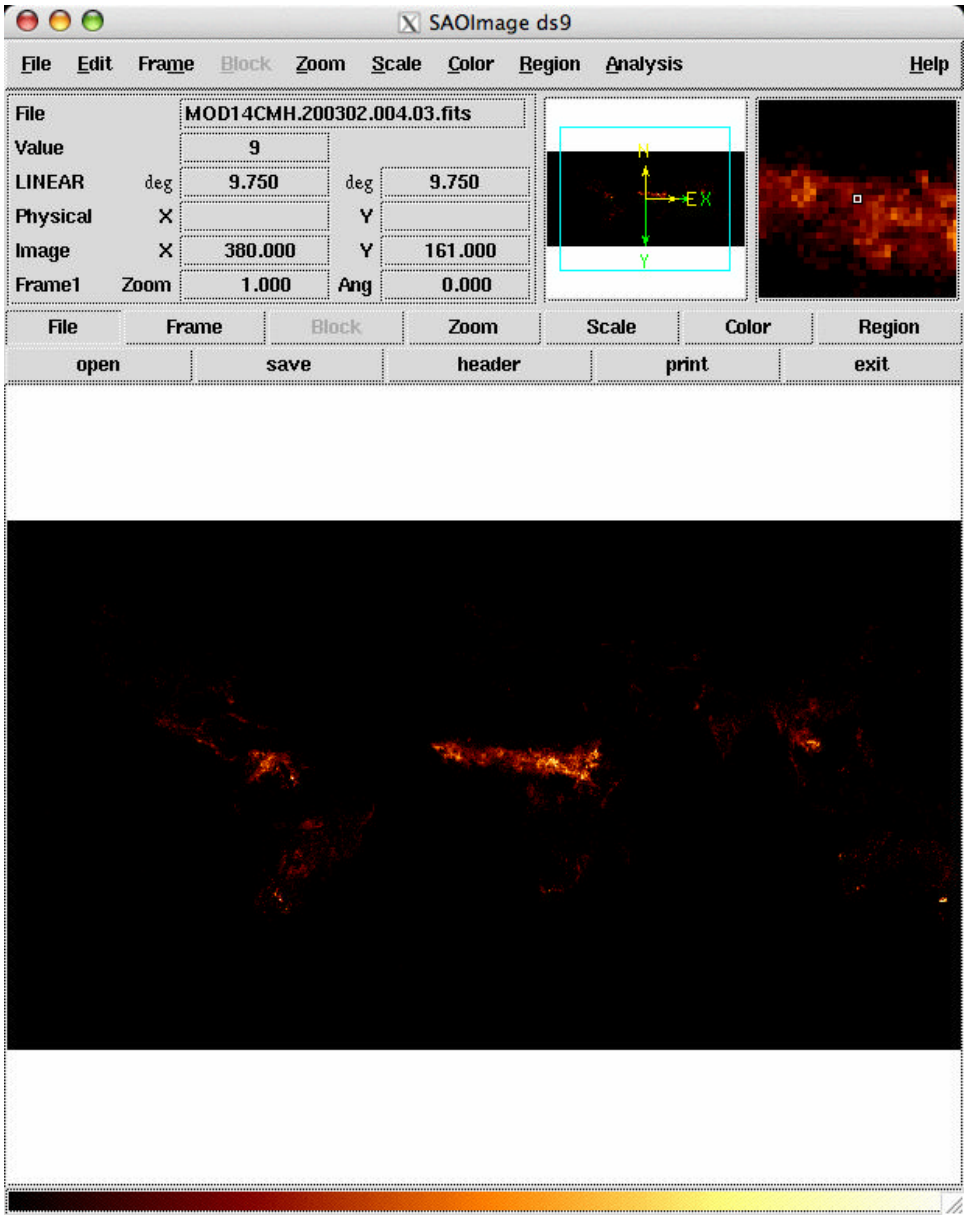

SAOImage ds9
File Edit Frame Block Zoom Scale Color Region Analysis Help
File MOD14CMH.200302.004.03.fits
Value 9
LINEAR deg 9.750 deg 9.750
Physical X Y
Image X 380.000 Y 161.000
Frame1 Zoom 1.000 Ang 0.000
File Frame Block Zoom Scale Color Region
open save header print exit

Figure 9: DS9 displaying the `CorrFirePix` data layer in the February 2003 MOD14CMH product. The longitude and latitude, respectively, at the center of the pixel beneath the cursor is shown in the upper left hand corner of the window, in the two numeric fields to the right of the word "LINEAR".

6.7 Hierarchical Data Format (HDF)

6.7.1 What are HDF files?

The Hierarchical Data Format (HDF), developed at the National Center for Supercomputing, is one of various file formats used to portably archive and distribute scientific data. HDF files are more or less "self-describing" in that they can include extensive metadata about the data stored within the file. Note that there are two *incompatible* flavors of HDF in use: HDF4, the format in which all MODIS products are stored, and HDF5, which is actually a completely different file format that is not backwards-compatible with HDF4. See the NCSA HDF web site for more information[6].

6.7.2 How do I read HDF4 files?

If you are writing your own software in a "traditional" programming language such as C or Fortran, you will need obtain the HDF4 library from NCSA[7]. Some commercial software packages, however, including MATLAB, IDL, and ENVI, have the HDF library built-in, in which case you will not need to install the library.

6.7.3 Can't I just skip over the HDF header and read the data directly?

Put any thought of reading or writing HDF files without the HDF library out of your head. HDF was intended to be not so much a physical file format, but instead an "application interface". As such, the format is fairly complicated (and has in fact changed over time) and it would be very time consuming (and risky) to roll your own HDF ingest code. The physical file format is nothing like the typical header-followed-by-data common to many other formats, and it is not easy to simply skip over the metadata fragments in an HDF file.

6.7.4 How can I list the contents of HDF4 files?

The NCSA HDF4 Library includes a utility named `ncdump` which will do this. Be sure to use the switch `-h` otherwise you will be inundated with ASCII dumps of all numeric arrays in the file.

[6] `http://hdf.ncsa.uiuc.edu/`
[7] `http://hdf.ncsa.uiuc.edu/hdf4.html`

7 References

7.1 Journal Papers and Technical Reports

Giglio, L., Descloitres, J., Justice, C. O., and Kaufman, Y., 2003, An enhanced contextual fire detection algorithm for MODIS. *Remote Sensing of Environment*, 87:273-282.

Giglio, L., and Kendall, J., 2003, *TRMM VIRS Monthly Fire Product User's Guide*, Revision B. (ftp://lake.nascom.nasa.gov/data/TRMM/VIRS_Fire/docs/VIRS_Fire_Users_Guide_B.pdf).

Justice, C. O., Giglio, L., Korontzi, S., Owens, J., Morisette, J., Roy, D., Descloitres, J., Alleaume, S., Petitcolin, F., and Kaufman, Y., 2002, The MODIS fire products. *Remote Sensing of Environment*, 83:244-262.

Kaufman, Y., Ichoku, C., Giglio, L., Korontzi, S., Chu, D. A., Hao, W. M., Li, R.-R., and Justice, C. O., 2003, Fires and smoke observed from the Earth Observing System MODIS instrument – products, validation, and operational use. *International Journal of Remote Sensing*, 24:1765-1781.

Kaufman, Y. J., Justice, C. O., Flynn, L. P., Kendall, J. D., Prins, E. M., Giglio, L., Ward, D. E., Menzel, W. P., and Setzer, A. W., 1998, Potential global fire monitoring from EOS-MODIS. *Journal of Geophysical Research*, 103:32215-32238.

Morisette, J., Giglio, L., Csiszar, I., and Justice, C. O., 2002, Validation of the MODIS Active fire product over Southern Africa with ASTER data. *International Journal of Remote Sensing*, in press.

Morisette, J. T., Giglio, L., Csiszar, I., Setzer, A., Schroeder, W., Morton, D., and Justice, C. O., 2005, Validation of MODIS active fire detection products derived from two algorithms. *Earth Interactions*, 9(9):1-25.

Roy, D. P., Borak, J. S., Devadiga, S., Wolfe, R. E., Zheng, M., and Descloitres, J., 2002, The MODIS Land product quality assessment approach. *Remote Sensing of Environment*, 83:62-76.

7.2 Relevant Web and FTP Sites

- **MODIS Fire and Thermal Anomalies**: General information about the MODIS Fire (Thermal Anomalies) and Burned Area products.
  http://modis-fire.umd.edu/
- **MODIS File Specifications**: Detailed file descriptions of all MODIS land products.
  ftp://modular.gsfc.nasa.gov/pub/LatestFilespecs/
- **MODIS LDOPE Tools**: A collection of programs, written by members of the Land Data Operational Product Evaluation (LDOPE) group, to assist in the analysis and quality assessment of MODIS Land (MODLAND) products.
  http://LPDAAC.usgs.gov/landdaac/tools/ldope/info/about.asp
- **MODIS Reprojection Tool (MRT), Release 3.2a**: Software for reprojecting tiled MODIS Level 3 products into man different projections. *http://LPDAAC.usgs.gov/landdaac/tools/modis/index.asp*

- **MODIS Web Fire Mapper**: Generates custom maps of active fires detected by the Terra and Aqua MODIS instruments. Users can also active fire locations in ESRI shape file and ARC/INFO formats. *http://maps.geog.umd.edu/*

- **MODIS Rapid Response System**: Access to near-real time Terra and Aqua MODIS reflectance, fire, vegetation index, and land surface temperature imagery. Includes a multi-year archive.
  http://rapidfire.sci.gsfc.nasa.gov/

- **EOS Data Gateway at the LP-DAAC**: The primary distribution site for most of the MODIS land products.
  http://edcimswww.cr.usgs.gov/pub/imswelcome/

- **MODIS Land Product Quality Assessment**: Product quality-assessment (QA) related information, including a very complete archive of known land-product issues with descriptions and examples.
  http://landweb.nascom.nasa.gov/cgi-bin/QA_WWW/newPage.cgi